Hospital Adoption of Medical Technology: An Empirical Test of Alternative Models

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Objective. This study examines hospital motivations to acquire new medical technology, an issue of considerable policy relevance: in this case, whether, when, and why hospitals acquire a new capital-intensive medical technology, magnetic resonance imaging equipment (MRI).

Study Design. We review three common explanations for medical technology adoption: profit maximization, technological preeminence, and clinical excellence, and incorporate them into a composite model, controlling for regulatory differences, market structures, and organizational characteristics. All four models are then tested using Cox regressions.

Data Sources. The study is based on an initial sample of 637 hospitals in the continental United States that owned or leased an MRI unit as of 31 December 1988, plus nonadopters. Due to missing data the final sample consisted of 507 hospitals. The data, drawn from two telephone surveys, are supplemented by the AHA Survey, census data, and industry and academic sources.

Principal Findings. Statistically, the three individual models account for roughly comparable amounts of variance in past adoption behavior. On the basis of explanatory power and parsimony, however, the technology model is "best." Although the composite model is statistically better than any of the individual models, it does not add much more explanatory power adjusting for the number of variables added.

Conclusions. The composite model identified the importance a hospital attached to being a technological leader, its clinical requirements, and the change in revenues it associated with the adoption of MRI as the major determinants of adoption behavior. We conclude that a hospital's adoption behavior is strongly linked to its strategic orientation.

Key Words. Diffusion, adoption, technology, magnetic resonance imaging, hospitals, models

The proliferation of new technologies that provide possibly beneficial new treatments, cures, and diagnostic techniques have driven costs upward, increasing the medical options available and the costs of treatment and diagnostic regimens. Yet, to implement an effective policy to control the proliferation and utilization of new technology, policymakers must understand why organizations acquire new medical technologies and why patients seek and select these new options. We address this general question by examining the factors affecting whether and when a hospital acquires a specific new capital-intensive medical technology: magnetic resonance imaging (MRI) equipment.

A variety of factors have made hospital decision making about the acquisition of MRI unusually complex. The regulatory environment that existed when MRI was first commercially introduced was unpredictable due to major changes in the hospital reimbursement system, state certificate-of-need regulations, the federal tax code, and uncertainty about the creation, interpretation, and enforcement of federal and state regulations (Kimberly, Renshaw, Ramsey, et al. 1989). Moreover, since MRI was the first capital-embodied technology to be released under Medicare's PPS and to be subject to premarket approval by the FDA, we are able to examine the impact of a new regulatory environment on the timing of adoption by hospitals. Technological change, product obsolescence, and questions about clinical efficacy, optimal product configuration, unit reliability, and operating costs were sources of technological uncertainty as well. Finally, uncertainty about market size and the potential uses of MRI made forecasts of demand difficult (Teplensky 1990). Thus, MRI adoption was an uncertain, risky, and complex process.

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MOTIVATIONS FOR ADOPTION: AN INTEGRATED PERSPECTIVE

Three different rationales for hospital adoption of technology have permeated the literature. They parallel Greer's (1985) interpretations of the hospital's three decision systems: fiscal-managerial, strategic-institutional, and medical-individualistic. Yet none of the perspectives alone has been able to explain technology adoption by hospitals satisfactorily, although it is likely that dominant motivations may exist within individual hospitals as a result of their strategic intent, demographic characteristics, or dominant coalitions. Perhaps each perspective only partially captures motivations for acquiring new technology when, in reality, they are multifaceted. Rather than being mutually exclusive, these explanations may be complementary. To test this possibility, we have incorporated elements of each of these perspectives into an integrated model to explain hospital adoption of MRI. We assess empirically how well this model explains variability and predicts the likelihood and timing of hospital adoption of MRI, controlling for regulatory differences, market structure, and organizational characteristics, and we compare the results with those of the individual models. However, before we provide the results of our integrated model, it is necessary to recognize how each of these perspectives differs.

The first view, which underpinned arguments for the DRG system, linked hospital behavior to anticipated financial returns. DRG advocates argued that hospitals would be motivated by potential profits to cut length of stay, trim technological intensity, and search for more profitable patients. For the minority of hospitals that are investor owned, profit maximization is an obvious motivator of behavior. For nominally not-for-profit hospitals, the hypothesis of profit motivation has been proposed by some authors (cf. Danzon 1982). Comparisons of not-for-profit and investor-owned hospitals do in fact show little difference in cost, quality, or production as a function of ownership (Gray 1986). More specifically, a hospital will acquire MRI technology when and if such investment maximizes the profits available to the firm, based on an assessment of the expected present values of the cost and revenue streams associated with acquiring MRI. Thus, expected profitability is hypothesized to be the principal determinant of adoption of new medical technology, and adoption will depend on factors that affect perceptions of current or projected costs and revenues. These perceptions would be particularly relevant in the case of diagnostic imaging, since procedures performed during a hospitalization that do not shorten length of stay, substitute for another procedure, or reduce the need for treatment increase the marginal costs to be absorbed by the hospital (Steinberg 1985).

In a static scenario, levels of costs and revenue/demand are expected to persist at current levels for the foreseeable future; the investment is compared to the "user cost of capital." Net revenue varies with the cost of the labor and supply inputs used to produce MRI scans. The user cost of capital depends on the price of MRI equipment, the opportunity cost of funds (implicit interest rate), the depreciation rate, and the tax advantages, if any. The implicit interest rate to a hospital, in the absence of a perfect capital market, may depend on the overall level of hospital net revenues and the hospital's overall capital structure. There are two modifications to this model. First, MRI may do more than produce revenues of its own by enhancing the price or quantity of other services the hospital can sell due to reputation effects, or because MRI is a strong complement to other services. Second, the essence of a process of diffusion is that variables are not constant; both revenues and costs are expected to change in the future, and in ways that differentially affect some firms relative to others. Building such potential future profit considerations into a theoretical model is exceedingly complex.

The second perspective, which we call technological preeminence, is grounded in the belief that hospitals adopt new capital-intensive medical technologies (no matter how costly) in order to enhance their image as technological leaders, thus attracting physicians and patients. Patients frequently associate new technology with high quality of care, and technically advanced facilities attract medical students, residents, fellows, and researchers as well. Moreover, this strategy meets the desires of administrators to run an up-to-date institution of high quality and prestige, and of doctors to have their workshop equipped with the latest tools (Pauly and Redisch 1973). It is further perpetuated by the emphasis on sophisticated technology in medical education (Steinberg, Sisk, and Locke 1985a).

The "technological imperative," as described by Fuchs (1968) and others, views hospitals as driven by supply, and not by either patient demand or market competition. A more recent modification of this model postulates that the strength of this imperative will be greater in more competitive markets than in less competitive markets, at least as long as price competition is inhibited by virtually complete conventional medical coverage (Luft, Robinson, Garnick et al. 1986). Technology thus serves as a form of nonprice competition for hospitals vying for physicians and patients.

A differentiation strategy based on technological leadership (Porter 1980) is also consistent with this rationale. The intent is to provide (or appear to provide) unique products or services in order to attract consumer attention. There are many bases upon which to found a differentiation strategy. One that appears to have great momentum among hospitals is technological leadership. A subset of hospitals has always differentiated itself on the basis of technological leadership, but as competitive pressures have increased over the last decade, a broader range of hospitals have embraced this strategy. Historically limited primarily to large teaching hospitals, a strategy of differentiation based on technological leadership has today been adopted by hospitals of all sizes and types, and by alternative health care delivery systems, particularly in major urban centers. This change may be due to increased competition from a greater variety and availability of health care delivery options, cost pressures from private industry and the government, and the elimination of the stability of a "highly regulated" industry.

Technological change and expectations about future innovations strongly affect an organization's decision about whether or not to adopt a new technology or to delay consideration (Balcer and Lippmann 1984; Teplensky 1990). Poorly timed commitments to new equipment could leave a hospital with a costly investment in an unproved technology. Early equipment may have more limited capabilities than later models, thereby limiting a hospital's ability to offer the most current clinical applications (Porter 1980). Early adopters, therefore, may have to write off earlier investments, upgrade their equipment, or limit their services to supporting earlier applications (Teplensky 1990).

Thus, one would posit, in general, a negative relationship between likelihood of adoption and uncertainty about MRI unit type, magnet size and type, and technological obsolescence. Yet, for organizations that position themselves as technological leaders, we hypothesize no significant effect, all else being equal. We posit that hospitals striving for technological leadership will be less likely deterred by technological uncertainty because maintaining an image as a technological leader requires early adoption of new technology. Moreover, the uncertainties associated with early adoption of MRI may be mitigated by the structure of the hospital's ownership and siting relationships (Hillman and Schwartz 1986) and by previous experience with related technologies (Teplensky 1990). For example, uncertainty might be reduced by entering into limited relationships such as leasing or partial ownership, or through learning based on related technological or operational experience.

A third perspective focuses on the provision of needed services, as defined by physicians or the hospital's medical staff. The basic hypothesis underlying this perspective is that hospitals and physicians adopt new technology based on their best determination of the actual clinical needs of the populations they serve, even if financial, competitive, or prestige considerations suggest alternative actions. That is, they will adopt a service patients need even if it loses money and adds nothing to the prestige or competitive position of the hospital, and they will not adopt a highly profitable, prestigious, new service if their patients do not really need it. This presumes that hospitals act as agents on behalf of their patients, either directly or as a result of physician requests, and that physicians, as the patients' agents, make decisions solely on the basis of their best clinical judgment of patient needs. Therefore, a hospital with greater clinical needs will be more likely to adopt MRI than another hospital, regardless of the other factors mentioned earlier.

One might argue that a clinical need exists as long as at least one patient can benefit from the service; yet it is implausible to assume that adoption will occur in such "marginal" cases. One modification to the model to avoid this dilemma is to postulate a threshold of clinical need, that is, a proportion or number of patients who benefit that must be exceeded for adoption to occur. The other modification is to note that hospitals have limited resources and must make decisions that will meet the clinical needs of the greatest proportion of their patient populations. Under this model, the hospital acts as the agent for its entire patient population, determining its threshold for adoption on the basis of the volume of patients requiring a technology and the total amount of resources available to the institution. Although individual physicians may act as patients' agents, the decision to acquire expensive technologies is made at the organizational level. Hence, the hospital's purchase decision may represent the aggregation of individual physicians' requests or the interaction of the administration's and physicians' goals. However, adding a financial resources constraint to the model necessarily mixes the clinical excellence model with the profit maximization model.

METHODOLOGY

SAMPLE SELECTION AND INSTRUMENTATION

The initial sample (637 hospitals, 80 percent response rate) consisted of every entity in the continental United States that owned or leased an MRI unit as of 31 December 1988, plus a stratified random sample of nonadopters. The names of the adopters were provided on a confidential basis by all MRI manufacturers with domestic sales. One hundred thirty hospitals were dropped from the analysis due to missing data (discussed further on), resulting in a final sample size of 507 (64 percent). Although the sample is truly a population of all MRI adopters in the United States, the analyses in this study are limited to hospital-owned or -sited MRI units. A hospital was considered to have owned an MRI unit if it was either a full or a partial owner of a unit, regardless of who its partner might be, or if it leased an MRI unit for its use.[1] Since an understanding of the competitive conditions facing the hospitals is a critical aspect of these analyses, data were collected on all MRI units in the market, regardless of ownership or siting. A stratified random sample of hospitals based on five bed-size levels was drawn from the American Hospital Association (AHA) database. Those hospitals which had not leased or purchased an MRI unit by 31 December 1988 were retained as the nonadopter sample. An attempt was made to sample equal numbers of adopters and nonadopters from each bed-size category. However, because the majority of hospitals in the larger bed-size categories (400–499 and greater than 500 beds) had adopted MRI units, this was not always possible.

Two telephone surveys, supplemented by the American Hospital Association survey, the Area Resource Files (ARF), and industry and academic sources provided the data for this study. The first survey, conducted in 1986 and then updated in late 1988, interviewed members of radiology departments who were knowledgeable about their MRI equipment. They were asked about unit siting and ownership, their possession of other equipment-embodied medical technologies, and to describe the MRI unit brand and specifications. The second survey, conducted in late 1988 through early 1989, asked hospital CEOs about their organization's decision-making processes regarding the acquisition of MRI capability and their perceptions of the competitive, technological, and regulatory environment. Nonadopters (those who had never considered acquiring MRI, those who were currently considering adopting MRI, and those who had decided not to acquire an MRI unit) were asked about the factors that might cause them to consider or reconsider adoption of an MRI unit.

Key informants have been widely used in sociology, management, and marketing studies to obtain data on organizational level variables (Anderson 1987; Brown and Lusch 1992; Campbell 1955). This method of data collection provides an alternative way to measure organizational characteristics, which may differ significantly from information gleaned through the aggregation of individual responses requesting data at a more "micro" level. This is because key informants are selected to report on the "organizational perspective" based on their access to key information and their ability to observe relevant actions or exchanges (Campbell 1955; Seidler 1974). Thus, they are also an economical way to get rich data. However, this method is also subject to potential biases and information deficiencies, both of which may distort the informant's judgments about the organization. The ideal study design would have included input from multiple informants, since perceptual differences may exist among the coalitions that participate in hospital decision-making. However, budget constraints would have required reducing our sample size in order to achieve this objective. Thus, the decision was made to survey a greater number of sites and to limit the number of respondents per organization.

Although the use of a single informant might bias the results, it is not unreasonable to assume that the source of bias would be consistent across all of the organizations. This is because individuals in similar positions are likely to have similar access to information and similar biases based on common training and experiences (Seidler 1974). We surveyed informants in the same position in each organization, utilizing a standardized interview protocol. While access to detailed information might differ for CEOs of hospitals of differents sizes (i.e., CEOs of smaller hospitals may be more familiar with the details of hospital operations), this was not a concern in our study, since the majority of our questions asked about organizational level variables and perceptions of the competitive environment. Furthermore, the only detailed transaction that was discussed was the acquisition of MRI, which for most of the organizations surveyed constituted a large and highly visible investment and thus required the active involvement of the CEO. Thus we feel that the advantages of using the CEO as the sole key informant outweigh any disadvantages inherent in relying on a single respondent, and provide an important and useful perspective on the hospital adoption decision-making process.

Collecting data retrospectively raises the issue of endogeneity of the dependent variable. It is true that retrospective, perceptual data may not tell us what "really" happened. However, an extensive literature on cognition and decision-making, supported by empirical evidence, argues that even public information that is evaluated using common techniques and heuristics, is perceived, interpreted, and responded to differently by individuals. Environmental stimuli may be interpreted in many ways and thus may lead to different actions by individuals (Dill 1958). Thus, "objective" archival measures would be inappropriate for a study of adoption decision-making. However, it is possible that respondents are "remembering facts" that may be perceived differently after the adoption decision occurred. But short of having had access to hospital discussions both before and during the time of the adoption decision, retrospective measures are the best alternative. At a minimum, we can at least say whether the hospital CEO believed that adoption decisions were based on these factors.

MEASURES

Since direct measures of expected MRI revenues, profits, and costs were not available, we used perceptual measures of MRI profitability and measures (for a subsample of hospitals) of actual total net revenue margins for the hospital. The latter is assumed to be a proxy for the internal cost of investment funds. The survey asked about profit expectations and the CEO's opinion of the importance of those profit considerations in the timing and the fact of a decision to adopt MRI. The two major measures of anticipated MRI profitability were the expected effect of MRI on the hospital's ability to be price competitive (PRICE) and the hospital's expectation that MRI acquisition would have a large influence (presumably positive) on the hospital's net revenue (NETREV). The latter variable should be positively related to the probability of acquisition. The anticipated effect of MRI on the hospital's ability to be price competitive, one might hypothesize, is higher in situations in which the hospital expects the market to be able to absorb the relatively high price of MRI services; adoption is assumed to be more likely in such circumstances. Each variable is a binary indicator where 1 indicates a large or moderate anticipated benefit associated with the adoption of MRI, zero otherwise. In addition, a five-point Likert-scaled variable, PRICEDEV, indicated the importance of being price competitive in the hospital's market development strategy. Table 1 summarizes the measures and the hypotheses. Table 2 provides descriptive statistics for the measures.

The costs and revenues associated with MRI should affect the probability of adoption. High cost for MRI site preparation, low levels of expected MRI reimbursement, and expected negative effects of PPS on MRI (whether founded or unfounded) would be expected to be negatively associated with adoption. Greater involvement of the hospital's chief financial officer in any decision would suggest greater concern for the hospital's overall profitability in situations in which the financial attractiveness of MRI adoption was uncertain and would be expected to be negatively correlated with adoption.[2] Finally, objective measures of the hospital's overall profit margin and ability to add debt might be expected to be positively related to the adoption decision.

Two categorical variables were used to capture the influence of the cost of the MRI unit (UNITAMT) and the cost of site preparation (PREPAMT) on

Table 1: Description of Measures

Variable Name	Description	Source	Hypothesized Effect
Control Variables			
HOSPS2	Number of hospitals in MSA	ARF 1985	
PCHOSP	Hospitals in MSA per 100,000 people	ARF 1985	
POP1980A	MSA population	ARF 1985	
LOCOMP	Number of local competitors	CEO Surv	
NOLOCOMP	Number of nonlocal competitors	CEO Surv	
INPCOMP	Level of competition in market area for inpatient care	CEO Surv	
OUTPCOMP	Level of competition in market area for outpatient care	CEO Surv	
BSC1	Average number of beds in hospital from 1983–86, broken into 6 categories from GT 500 beds to LT 100 beds	AHA	
TEACHOSP	Member of the Council of Teaching Hospitals (COTH)	AHA	
RESTRUC	Whether the hospital had been restructured in prior 3 years	CEO Surv	
CONREQ	Whether CON approval is or was required for hospital-based MRI units	CEO Surv	
CONDIFFH	Difficulty of CON approval for hospital-based MRI units	CEO Surv	
CONDIFFN	Difficulty of CON approval for nonhospital-based units	CEO Surv	
CONREG1	Difficulty of CON approval for MRI units	HCIA	
CONSCORE	CON stringency overall	Manheim	
RATEREG	Extent of state rate regulation	Manheim	
Technology Variables			
OBSOLTE1	Effect of concern about early obsolescence on MRI acquisition decision	CEO Surv	–
UNCUNIT1	Effect of uncertainty about type of MRI unit to get on MRI acquisition decision	CEO Surv	–
UNCMAG1	Effect of uncertainty about MRI magnet size and type on MRI acquisition decision	CEO Surv	–
TECHDEV	Importance of being perceived as a technology leader in hospital's market development strategy	CEO Surv	+
DEVSTRAT	Most important market development strategy is being perceived as a technology leader	CEO Surv	+
TECHTYPE	Emphasis on high-technology products, programs, or services	CEO Surv	+
Clinical Variables			
HOSPKIND	Type of hospital	CEO Surv	+
IDEA1	Source of idea to acquire an MRI unit	CEO Surv	+
INVOLVE	High involvement in the decision whether or not to acquire an MRI unit by a member(s) of the medical staff	CEO Surv	+

Continued

Table 1: Continued

Variable Name	Description	Source	Hypothesized Effect
PROVCLIN	Influence of proved clinical applications on respondent's decision to acquire MRI	CEO Surv	+
POTCLIN	Influence of potential clinical applications on respondent's decision to acquire MRI	CEO Surv	+
CDELSTRA	Characterization of hospital's current service delivery strategy	CEO Surv	–
CLINTYPE	Emphasis on providing basic products, programs, and services that require MRI technology	CEO Surv	+
MOREBEDS	Increase in the number of permanent acute care beds	CEO Surv	+
SEVERITY	Hospital case-mix severity	CEO Surv	+
Financial Variables			
HMARGIN	Hospital operating margin	HCIA	+
CFOMRI	Strong CFO involvement in MRI acquisition decision	CEO Surv	–
PRICE	Anticipated influence of MRI on hospital's ability to be price competitive	CEO Surv	+
NETREV	Anticipated influence of MRI on hospital's ability to enhance net revenue	CEO Surv	+
UNITAMT	Influence of the cost of the unit on respondent's decision to acquire MRI	CEO Surv	–
PREPAMT	Influence of the site preparation cost on respondent's decision to acquire MRI	CEO Surv	–
REIMB2A REIMB2B	Influence of level of MRI reimbursement on decision to acquire MRI	CEO Surv	+/–
CAPITAL	Influence of hospital's capital availability on decision to acquire MRI	CEO Surv	+
PPS	Influence of concern about effect of PPS on decision to acquire MRI	CEO Surv	–
PRICEDEV	Importance of being price competitive on hospital's market development strategy	CEO Surv	+

the respondent's adoption decision. REIMB2A/2B, a two-variable dummy indicator, measured the influence of the level of MRI reimbursement on the hospital's decision to acquire MRI. REIMB2A captured if the level of reimbursement was a positive influence; REIMB2B captured if it was a negative influence. If reimbursement had no influence at all, both were coded zero. Two variables measured the hospital's ability to make large capital investments. HMARGIN, which was available only for hospitals with more than 300 beds, measured the hospital's operating margin. CAPITAL, a binary variable, indicated whether or not the hospital's capital availability influenced its decision

Table 2: Descriptive Statistics

Variable	*Mean*	*s.d.*	*Minimum*	*Maximum*	*Median*
HOSPS2	171.23	607.13	1	302.1	26
PCHOSP	2.57	0.92	0.80	5.98	2.4
POP1980A	4310(000)	11197(000)	71.9(000)	5592(000)	1243(000)
LOCOMP	4.26	5.12	0	70	3
NOLOCOMP	3.23	5.2	0	61	2
INPCOMP	3.94	1.1	1	5	4
OUTPCOMP	3.78	1.14	1	5	4
RESTRUC	0.41	0.49	0	1	0
CONREQ	0.79	0.41	0	1	1
CONDIFFH	2.71	1.12	1	4	3
CONDIFFN	2.03	1.15	1	4	2
CONREG1	2.15	0.83	1	4	2
CONSCORE	7.82	3.52	0	15	9
RATEREG	0.76	0.75	0	2	1
OBSOLTE1	0.40	0.49	0	1	0
UNCUNIT1	0.24	0.42	0	1	0
UNCMAG1	0.34	0.47	0	1	0
TECHDEV	4.54	0.74	1	5	5
DEVSTRAT	0.36	0.48	0	1	0
TECHTYPE	0.89	0.31	0	1	1
HOSPKIND	0.52	0.50	0	1	1
IDEA1	0.30	0.46	0	1	0
INVOLVE	0.54	0.5	0	1	1
PROVCLIN	0.94	0.24	0	1	1
POTCLIN	0.91	0.28	0	1	1
CDELSTRA	0.27	0.44	0	1	0
CLINTYPE	0.09	0.28	0	1	0
MOREBEDS	0.21	0.41	0	1	0
SEVERITY	0.89	0.32	0	1	1
HMARGIN	−1.81	25.8	−300.4	109.4	2.9
CFOMRI	0.58	0.49	0	1	1
PRICE	0.67	0.47	0	1	1
NETREV	0.76	0.43	0	1	1
UNITAMT	0.66	0.47	0	1	1
PREPAMT	0.57	0.5	0	1	1
REIMB2A	0.24	0.43	0	1	0
REIMB2B	0.46	0.50	0	1	0
CAPITAL	0.64	0.48	0	1	1
PPS	0.65	0.48	0	1	1
PRICEDEV	3.81	1.14	1	5	4

to adopt MRI. Finally, the chief financial officer's level of involvement in the adoption decision was captured by a binary variable (CFOMRI). The level of the CFO's involvement in the decision-making process was measured by a ten point Likert scale. When the CFO's involvement met or exceeded the median involvement for all CFOs, CFOMRI was coded 1; zero otherwise. With the exception of the operating margin data (HMARGIN), which was provided by HCIA analysts, all of the financial data were drawn from the CEO interviews.

Technological change and product obsolescence, combined with questions about clinical effectiveness, MRI unit reliability, and the cost of after-sale service, resulted in technological uncertainty for organizations considering the adoption of an MRI unit in the early years of its availability (ECRI 1985; Office of Medical Applications Research 1987). Debates about clinical efficacy, high switching costs due to a lack of standardization, and questions about optimal product configurations made unit selection an uncertain and complex process as well (Iezzoni, Grad, and Moskowitz 1985). Decisions had to be made about unit mobility (fixed or mobile) and weight, magnet size and type, shielding, and the software and special equipment necessary for more advanced uses (Hillman and Schwartz 1986). Since many of the early companies were new firms created to manufacture and distribute MRI equipment, questions existed about their reputations, longevity, and product quality as well (Teplensky et al. 1993). Three dummy variables were used to capture technological uncertainty. They measured the effect of concern about early obsolescence (OBSOLTE1), uncertainty about the type of MRI unit to get (UNCUNIT1), and uncertainty about MRI magnet size and type (UNCMAG1), on the hospital's adoption decision. If these factors had a negative influence on that decision, the variables were coded 1; otherwise they were coded zero.[3]

Mitchell (1989) found that organizations that perceived a threat to their core products or specialized supporting assets by new businesses or markets were more likely to enter those markets earlier than competitors that did not feel so threatened. Similarly, we would expect organizations that have built reputations as technological leaders to view the entry of a new technology into their marketplace as a threat to that image (Teplensky 1990). Hence, we hypothesize that the hospital whose image as a technological leader is important to its market development strategy, or one that has invested heavily in high-technology products, programs, or services, would be likely to adopt MRI early.

Several variables measured the hospital's positioning as a technological leader. The importance of being perceived as a technology leader (TECHDEV) was measured by a five-point Likert scale. Whether or not the hospital's most important market development strategy was "to be perceived as a technology leader" was represented by a dummy variable (DEVSTRAT). Finally, a dummy variable (TECHTYPE) was used to represent whether or not the hospital emphasized high-technology products, programs, or services. This categorization was based on the CEO's response regarding the hospital's three most important products, services, or programs and their subsequent assignation to 15 categories, each of which was later assigned a value based on high-technology orientation. All six of the technology variables are perceptual measures from the CEO survey.

Several variables factored into a hospital's assessment of its clinical need for MRI. If it was a national or regional referral center (HOSPKIND), its case-mix severity (SEVERITY) or number of permanent acute care beds were increasing (MOREBEDS), or its emphasis was on services that drew heavily on MRI technology (CLINTYPE), it was expected that the anticipated demand for MRI would be higher; these variables would be positively associated with adoption. All of these measures were dummy variables. CLINTYPE represented whether the hospital's products, programs, and services focused on providing basic services that required MRI technology, as opposed to those that would be considered "cutting edge." A dummy variable (CDELSTRA) represented whether the hospital characterized its current delivery strategy as maintaining a traditional mix or increasing its focus on a few specialties (as opposed to diversification). Similarly, it was expected that the efficacy of the technology, as measured by proved (PROVCLIN) and potential (POTCLIN) applications, would positively influence adoption.

Since physicians are typically biased toward high technology, we expected high involvement in the adoption decision by the medical staff (INVOLVE) and the identification of the need for MRI by a member of the medical staff (IDEA) to also be positively correlated with adoption. Each was represented by a binary categorical variable. Whether or not members of the medical staff were highly involved in the adoption decision making was determined by the levels of involvement of the individuals active in the decision-making process as measured by a ten-point Likert scale. When the involvement of a member of the medical staff met or exceeded the median involvement for all medical staff, INVOLVE was coded 1; zero otherwise. Finally, both proved clinical applications and the anticipation of potential clinical applications were posited to be positively correlated with adoption. These were measured by binary variables where 1 indicated that their influence on the adoption decision was positive.

CONTROL VARIABLES

Control variables were divided into three categories: market structure, regulation, and organizational characteristics. The market structure variables consisted of both archival and perceptual measures. The archival measures were market population (POP1980A), number of hospitals in the respondent's MSA (HOSPS2), and the number of hospitals per capita (PCHOSP1), all provided by the Area Resource Files. The perceptual measures were drawn from the CEO survey. They were intended to measure the intensity of competition in the hospital's market (as defined by the CEO). The first two perceptual measures were the number of local (LOCOMP) and nonlocal (NOLOCOMP) competitors. The other two were Likert-scaled measures of the intensity of competition in the market for inpatient (INPCOMP) and (OUTPCOMP) outpatient care.

Six different measures were used to characterize the regulatory environment facing the hospitals during this time period. Four of these measures address different aspects of certificate-of-need (CON) regulations as they pertain specifically to MRI units. Of these, the first three are drawn from the CEO survey. The first (CONREQ) is a dummy variable that indicates whether CON approval was or is required for hospital-based MRI units. The next two measures are Likert-scaled variables indicating the CEO's perception of the difficulty of obtaining CON approval for hospital-based units (CONDIFFH) and nonhospital-based units (CONDIFFN). The fourth, a scale developed by Healthcare Analysts, Inc., grouped states by degree of difficulty for MRI entry. Rankings, which ranged from 1 through 4 (increasing stringency) considered such factors as the dollar threshold of investment that triggered review, whether nonhospital sites required review, and the program's propensity to reject MRI applications. Thus, states with lower investment thresholds, where off-site or nonhospital units were subject to review, and where the approval rate was lower, were considered more stringent. A hospital located in a state with a ranking of "1" would be in a regulatory environment where the CON approval process was less stringent than a hospital located in a state with a higher number. The last two measures of the regulatory environment–more general measures–have been provided by Manheim et al. (1992). The first measure (CONSCORE) is a stringency scale, ranging from 0 through 15, which is based on capital expenditure, medical equipment, new institutional services threshold levels, planning agency budget size, and the percentage of hospital applications approved. The second measure (RATEREG) categorizes states on the basis of the stringency of their rate regulation.

Three organizational characteristics were also included in each of the models: hospital size, as determined by the average number of hospital beds from 1983 through 1986 (BSC1); hospital membership in the Council of Teaching Hospitals (TEACHOSP); and whether or not the hospital had been part of a restructuring in the previous three years (RESTRUC). The first two variables are from the AHA survey; the data on restructuring are from the CEO survey.

Data Analysis: Likelihood and Timing of Adoption

Time of adoption was measured by contract date, broken down into monthly periods. For those hospitals that did not have contract dates or did not sign contracts, contract dates were estimated using the date on which the idea to acquire an MRI unit was proposed and the lag time until a final decision to acquire an MRI unit was made. Adoption constituted any commitment of resources (i.e., full or partial ownership, lease, or lease-purchase). The analyses of the likelihood of adoption at a specific time had an initial sample size of 507 observations (341 adopters, 166 nonadopters), which was 80 percent of our original sample. Due to missing contract date data, 130 cases were deleted from the original sample. Date of adoption ranged from 1 through 96, representing January 1981 through December 1988. The data were analyzed by Cox regression, using the PHGLM algorithm in SAS version 5.16. Cox regression models the probability that an event (in this case adoption) will occur at a specific time to an individual (hospital), given that the hospital is at risk at the time, without assuming a specific distribution underlying the timing of the event. Cox models include censored data in the analysis, so all hospitals contribute all of the information that is known about the hospitals, reducing the likelihood of biased coefficients.

Each of the individual models was run separately, as was a model comprised solely of the control variables, in order to assess the incremental impact of the hypothesized constructs. Initially, two financial models were analyzed. The first one omitted the operating margin variable, HMARGIN, since these data were not available for hospitals with fewer than 300 beds. The possibility of a substantial bias arises if all observations for which HMARGIN was unavailable were deleted in the analysis. The second financial model included HMARGIN and thus applied only to large hospitals. Subsequent to these analyses, a composite model consisting of all of the variables from each of the individual models, together with the control variables, was run and compared to the individual models. For the reasons just given, two models were run initially, one with HMARGIN and one without. In order to build a more parsimonious model without sacrificing the models' explanatory power, nonsignificant variables were deleted for subsequent analyses. The reduced models were compared to the full models using the likelihood ratio test, which compares the goodness of fit of two nested models.[4] Differences in the log-likelihoods and chi-square statistics using both the null model and the model with only control variables were also calculated to assess the additional incremental explanatory power of the models.

t-Values indicate the significance of individual variables and are used to test the null hypothesis that $B_x = 0$. The coefficients may be transformed into the change in odds associated with each variable by taking the antilog of the coefficient and subtracting one from it (Allison 1984). This is interpreted as the change in the base hazard (probability of adoption at a point in time given that the hospital is still at risk) associated with each one-unit change in the independent variable, all else held constant. For dummy variables, this value represents the change in the base hazard when the variable has a value of one. The changes in odds for the statistically significant variables in each of the models appear in Table 3.

Many of the comparisons conducted in this study are between non-nested models. This requires the use of a different set of measures to compare

Table 3: Full-Timing Models, Results of Cox Regressions

	Full-Timing Model				*Reduced-Timing Model*			
Variable	*BETA*	*SE*	p-*Value*	*% Change in Odds*	*BETA*	*SE*	p-*Value*	*% Change in Odds*
BSC1	0.120	0.063	.05	12.7	0.185	0.045	.0001	20.3
CONSCORE	−0.045	0.026	.09	−4.4	−0.057	0.017	.0008	−5.5
RATEREG	−0.200	0.105	.06	−18.1	−0.204	0.083	.01	−18.5
TECHDEV	0.382	0.118	.001	46.5	0.370	0.090	.0001	44.9
TECHTYPE	0.656	0.264	.01	92.7	0.680	0.233	.004	97.4
HOSPKIND	0.203	0.151	.18		0.252	0.123	.04	28.7
INVOLVE	0.423	0.152	.006	52.6	0.300	0.119	.01	35.0
CDELSTRA	−0.307	0.159	.05	−26.4	−0.243	0.134	.07	−21.6
CLINTYPE	0.465	0.253	.07	59.2	0.568	0.190	.003	76.5
CFOMRI	−0.291	0.139	.04	−25.2	−0.202	0.114	.08	−18.3
NETREV	0.384	0.170	.02	46.8	0.378	0.135	.005	45.9
PREPAMT	−0.230	0.179	.20		−0.269	0.114	.01	−23.6
PPS	−0.291	0.165	.08	−25.2	−0.300	0.122	.01	−25.9
Chi-square	146.65 (41)				153.35 (13)			
R-value	15.0%				18.4%			
Pseudo-R^2	5.1%				4.1%			
ALR	3.7%				3.7%			

the relative goodness of fit and predictive ability of the models. The PHGLM procedure provides an R-value, which measures the predictive ability of the model, adjusting for the number of parameters (SAS Institute 1986). It expresses the degree to which predictions based on the model fit the data. The likelihood ratio index, or pseudo-R^2, provides a measure of fit analogous to the R^2 in regression models (Chu and Anderson 1992, 13; Judge, Griffiths, Hill, et al. 1985, 774).[5] It is often difficult to determine if the difference in the likelihood ratio index between two models is large enough to offset a reduction in parsimony. Chu and Anderson (1992) suggest that the Akaike Likelihood Ratio Index (ALR), which is analogous to an adjusted R^2 in regression analyses, be used to guide this decision.[6] As with the adjusted R^2, this index penalizes models with variables that do not contribute enough to the model's explanatory power.

RESULTS

Two full models were run initially, one without HMARGIN and one including HMARGIN. No statistical difference between the two models was found, and HMARGIN was dropped from subsequent analyses. The model had a chi-square of 146.7 ($p = .0001$) and an R-value, pseudo-R^2, and ALR of 15 percent, 5 percent, and 4 percent, respectively. All of the significant coefficients were in the directions hypothesized. The importance of being perceived as technology leader to the hospital's market development strategy (TECHDEV) and whether the hospital has a high-technology orientation with respect to its product offerings (TECHTYPE) were positively related to likelihood of adoption, as hypothesized, increasing the odds of adoption by 47 percent and 93 percent. Involvement in decision making by the medical staff (INVOLVE) and strong clinical need (CLINTYPE) were positive, as we had predicted as well, increasing the odds of adoption by 53 percent and 59 percent. The negative coefficient for maintaining a traditional product mix as opposed to diversification (CDELSTRA), decreasing the odds of adoption by 26 percent, is not surprising either. The negative associations of CFO involvement in the decision making (CFOMRI) and the anticipated effect of Medicare's PPS with adoption also support our hypotheses. They each decreased the odds of adoption by 25.2 percent. The positive relationship between the anticipated effect of MRI on enhancing net revenue (NETREV) and adoption also supported our hypothesis and indicated that large revenue expectations associated with MRI increased the odds of adoption by 46.8 percent.

Since many of the variables were not statistically significant, an effort was made to make the model more parsimonious. Therefore, all of the strongly nonsignificant variables were dropped and the model was rerun (reduced model). The reduced model had a chi-square of 153.35 with 13 degrees of freedom ($p = .0001$) and R-value of 18.4 percent, and pseudo-R^2 and ALR of 4 percent. Since its log-likelihood is not statistically different from that of the full model, it is the preferred model. More importantly, the reduced model was not substantively different from the unrestricted model. All of the same variables were significant in the same directions, and the coefficients of OBSOLTE1 and UNCUNIT1 were constrained to be zero, as was determined empirically in the unrestricted model. The only differences were with respect to the magnitude of the effects of CLINTYPE and INVOLVE on the odds of adoption. The former increased from 59 percent to 77 percent, and the latter decreased from 53 percent to 35 percent. Furthermore, once some of the multicollinearity was reduced by eliminating redundant variables, the coefficients for national or regional referral centers (HOSPKIND) and site preparation costs (PREPAMT) became statistically significant as predicted. HOSPKIND increased the odds of adoption by 28.7 percent, whereas PREPAMT decreased it by almost 24 percent. The restricted model is also significantly better than a model that consists solely of its control variables (chi-square 66.8, 3 d.f.; R-value = 12.4 percent). These results are summarized in Tables 3 and 4. In order to provide a basis of comparison, models representing the individual perspectives were run.[7] The results indicate that the initial full model is statistically better than any of the individual models, although it does not add all that much more explanatory power adjusting for the additional variables.

In order to provide a basis of comparison in addition to the null model, a Cox regression was run using only the control variables. It had a chi-square of 60.29 with 16 degrees of freedom ($p = .0001$) and an R-value of 9.3 percent, pseudo R^2 equal to 2 percent, and ALR of 1 percent. Only five variables were statistically significant: the number of hospitals (HOSPS2) and the population in the MSA (POP1980A), hospital bed-size (BSC1), overall CON stringency (CONSCORE), and the stringency of rate regulation (RATEREG). The number of hospitals and average bed-size were positively associated with adoption; this is consistent with previous findings in the literature. Also, as expected, CON and rate regulation stringency were negatively associated with likelihood of adoption. Since so few variables were significant, many were collinear, and no prior theory existed to help us select among the variables, a reduced model, which contained only these five significant variables,

Table 4: Baseline Models–Control Variables Only, Cox Regression Results

	All Controls				*Smallest Control Model*			
Variable	*BETA*	*SE*	p-*Value*	*% Change in Odds*	*BETA*	*SE*	p-*Value*	*% Change in Odds*
HOSPS2	0.002	0.001	0.07	.2				
POP1980A	−0.000*	0.000*	0.05					
BSC1	0.204	0.051	0.0001	22.6	0.247	0.038	0.0001	28
CONSCORE	−0.039	0.024	0.09	−3.8	−0.049	0.016	0.002	−4.8
RATEREG	−0.173	0.091	0.06	−15.9	−0.294	0.077	0.0001	−25.5
Chi-square		60.29 (16)				66.80 (3)		
R-value		9.3%				12.4%		
Pseudo-R^2		1.9%				1.7%		
ALR		1.4%				1.6%		

was fitted to the data. Its chi-square was 70.53 with 5 degrees of freedom ($p = .0001$) and it had an R-value equal to 12.5 percent (pseudo $R^2 = 2\%$, ALR = 2%). There was no statistical difference in explanatory power between the full and reduced models, and the substantive interpretation remained unchanged. A subset of this model, containing only BSC1, CONSCORE, and RATEREG, had an R-value of 12.4 percent, a chi-square equal to 66.8 (3 d.f., $p = .0001$, and both a pseudo-R^2 and ALR of 2%). The results are summarized in Table 4.

DISCUSSION

The importance a hospital attached to being a technological leader, together with an emphasis on clinical services that required MRI and the change in revenues it believed to be associated with the adoption of MRI, were the major determinants of adoption behavior. Stringent regulations and financial concerns had large negative impacts. Of the control variables originally included in the model, only three–hospital size, the restrictiveness of CON regulation, and the stringency of rate regulation–were significant. Larger hospitals were more likely to adopt MRI early; teaching hospitals, on the other hand, were not more likely to adopt. This is probably because the variation in the data was accounted for by hospital size, hospital type, and the technological positioning variables.

Overall, CON stringency had a strong negative impact on adoption. For each one-point increase in CON stringency based on a 15-point scale, the odds of adoption among hospitals that had not yet acquired MRI decreased by 4.4 percent. Variables that dealt specifically with the impact of CON on MRI were not significant once overall CON stringency was accounted for. Finally, rate regulation stringency had a very strong negative effect. By changing to a mandatory all-payer prospective payment system from no hospital rate regulation at the state level except Medicaid, the likelihood of adoption would be reduced by more than one-third, all other factors equal. These findings are consistent with conventional wisdom on the effect of CON on CT diffusion a decade earlier (Hillman and Schwartz 1985). They also support earlier work by Romeo, Wagner, and Lee (1984), who found that restrictive rate setting discouraged the adoption of cost-increasing technologies while increasing the likelihood of adopting cost-decreasing technologies. Similarly, Steinberg, Sisk, and Locke (1985b) found that MRI diffused more slowly than CT; they attributed this to changes in reimbursement policies.

The likelihood of hospital adoption was strongly related to its strategic positioning as a technological leader. This was true whether all three sets of factors were considered simultaneously, as in the full model, or whether the analysis was limited to the technology variables. A hospital that attached great importance to being perceived as a technology leader had a much greater odds of adopting relative to a similar hospital that did not consider this perception to be important. Our model indicated that a one-unit change alone on a five-point scale would increase the odds of adoption by more than 45 percent. Alternatively, if the hospital switched its emphasis to high-technology services and other conditions remained the same, its odds of adoption would almost double. As expected, technological uncertainty did not serve as a deterrent to adoption. These results are consistent with prior work by Hillman, Neu, Winkler, et al. (1987), who found that the acquisition of MRI played a major role in hospital strategies for survival in the increasingly competitive environment. Hospitals felt strongly that acquiring MRI early was important in maintaining or expanding their local markets. The presence of competitor-owned units appeared only to heighten the sense of urgency.

High anticipated clinical need had a strong positive effect on the odds of adoption, as evidenced by the influences of hospital type and clinical orientation. This meant that if a hospital had a strong clinical need for MRI, it was much more likely to adopt (increasing the odds of adoption by at least 60 percent), even after controlling for technological, financial, and regulatory factors. Changing the level of medical staff involvement in the decision making to above the median also increased the odds of adoption in both the full and clinical models, although it did not matter if a member of the medical staff had the original idea to adopt. This is consistent with the findings by Alexander and Morrisey (1988) that physician involvement in hospital decision making was associated with increased hospital costs. Our article offers one explanation for why this may be so–through the purchase of expensive new technology. This positive influence of the medical staff may indicate physician preferences for technically advanced facilities, or it may be a proxy for clinical need. Our data do not allow us to discern the priorities of the medical staff involved in the decision making and thus to resolve this question.

The anticipated influence of MRI to enhance hospital net revenues had a substantial positive effect on the likelihood of adoption. A change in a hospital's expectation from little or no increase in net revenues to a large or moderate increase increased its odds of adoption by approximately 46 percent. The level of importance a hospital attached to being price competitive was a positive influence on adoption only in the financial model. Once technology and clinical variables were factored into the model, this no longer played a role in adoption decision making. Moreover, once these other factors were considered, both the involvement of the chief financial officer and site preparation costs negatively influenced adoption.

Although Pauly, Hillman, Kimberly, et al. (1989) found that PPS had no significant effect on the adoption of MRI, we found that the CEO's concern about the anticipated influence of PPS on the hospital decreased its likelihood of adopting by 25 percent, all other factors equal. This implies that fear of financial risk may be more influential than the actual realization of the financial consequences. This is consistent with Steinberg's (1985a,b) reasoning that uncertainty about Medicare's future capital expenditure policy would negatively influence the adoption of new medical technology.

CONCLUSIONS

The three individual models were all about equal in explaining past hospital adoption behavior. The advantage of the full model over the individual models is that it simultaneously controls for all of the factors being examined; this is important since it is not always clear where the boundaries lie among the three perspectives. The profit maximization perspective suggests that hospital adoption behavior is driven by administrative priorities, focusing on the need to maintain the hospital's fiscal health and hence revenue generation and cost reduction. The clinical excellence perspective highlights the role of medical priorities in the determination of hospital adoption behavior. It represents the commitment by the medical staff to maintain a range of capabilities in the hospital in order provide clinical services to patients. Although decision making based on clinical needs is common to all hospitals, competitive or financial factors may be given equal or greater consideration in some institutions. The technological preeminence argument, in contrast, appears to be driven by both medical and administrative goals. By acquiring the latest medical equipment, a hospital may not only generate additional revenues through the expansion of current services and growth in new strategic directions, but it may also attract new physicians capable of performing new medical procedures, enabling the hospital to better serve its patient population.

In fact, hospitals engaging in behavior consistent with the profit maximization and technological preeminence perspectives may yield similar outcomes because the primary differences behind these two drivers of adoption are (1) the priority given to profitability and (2) the strength of the linkage between adoption behavior and profitability. In the profit perspective, cost and revenue considerations are paramount, and the linkage between adoption and profit expectations is direct. In the technological preeminence view, greater technological sophistication may increase patient throughput, yielding greater revenues and profitability; however, this relationship is both indirect and moderated by factors such as the desire for prestige and physician preferences for technically advanced facilities. This may explain why the importance a hospital attached to being a technological leader and the change in revenues associated with the adoption of MRI were major determinants of hospital adoption.

CON and rate regulations appear to have a major limiting impact on the hospital adoption of new capital-intensive medical technologies. However, slowing MRI adoption by increasing regulatory constraints is possible only in states that have less stringent regulations and thus room for change. The options are more limited for states that already have stringent CON regulations. Nevertheless, although CON and rate regulations have negatively influenced past adoption behavior, adjusting these alone will not halt the proliferation of medical technology in hospitals.

The importance to the hospital of being a technological leader is one of the strongest determinants of hospital adoption behavior. A hospital's strategic orientation as a technological leader is likely to be difficult to change. Yet, as competition increases, managed care becomes more prevalent, and patient involvement in decision making increases, hospitals may have no choice but to alter their strategic orientations and to embrace policies that encourage greater market segmentation, cooperation, or specialization; these, in turn, will influence their adoption behavior. Moreover, to the extent that capital endowments are reduced by limits on reimbursements and lower operating margins due to increased competition, choices will have to be made. Increased involvement by CFOs in the decision making, reflecting greater institutional financial concerns associated with adoption of new technology, may lead to more constrained adoption behavior. Thus, interventions that affect hospital margins may decrease the likelihood of adoption, particularly under capitation or global budgets.

The clinical variables that were strongly positively related to hospital adoption of MRI are probably proxies for clinical demand associated with case mix and severity. Although demand can be manipulated by placing constraints on the physician (Greer 1987), such measures are likely to be unpopular with both physicians and patients. Expanding research on cost-effectiveness, and encouraging third party payers to scale their payments for new technology according to demonstrated clinical effectiveness and cost-effectiveness, are two feasible options that may influence clinical motivations and decision making about new technology. Patients can also be made to pay more of the real cost of new technology. This will likely encourage them to question whether the additional clinical effectiveness is worth the incremental cost. While this information is not yet widely available, health care reform will likely create incentives for patients to become more active consumers, or at least to question their physicians when copayments or deductibles are higher. At this time, however, employers and third party payers are most likely to be responsive to this type of information.

Hospital adoption of new technology is a complex process. Each of the perspectives discussed in this article has value for identifying those factors that policymakers can manipulate in the future in order to influence hospital decision making regarding the adoption of new capital-intensive medical technology. Many of these alternatives have several things in common: making consumers more aware of and possibly bearing the brunt of the real cost of procedures; forcing physicians and hospitals to question whether the increased clinical efficacy is worth the increased cost; and assessing whether the perceived clinical need is real and necessary. Research on the relative efficacies of treatments or new technologies is growing and should provide useful information that could influence the assessment of the clinical need for more technology. Managed care organizations and many hospitals have already developed formularies for pharmaceuticals, requiring newcomers to demonstrate their effectiveness and frequently their relative efficacy and cost-effectiveness. And although the specifics of health care reform are still unclear, and the impact of competition is still evolving, mechanisms such as global budgeting and capitation, which force hospitals to make trade-offs among alternative investments, appear to offer particular promise for slowing the rate of technology diffusion.

Our study has examined the adoption decision making process at the organizational level. Further insights may be gained by studying decision making at the level of coalitions or constituencies within hospitals, and the negotiation, bargaining, and compromise processes that occur among them. Given the proliferation of alternative governance structures for the delivery of health care, research is also warranted into whether these findings generalize to other provider populations. Research that explores the impact of the policy alternatives we have suggested on the adoption process will provide information useful for the development of future health care initiatives as well. Furthermore, investigation is warranted regarding whether these findings extend to non-equipment-embodied medical technology. Finally, we advocate a much more directed approach to understanding the adoption decision process, focusing specifically on the incentives and constraints created by regulation, competition, and strategic orientation, since our research has indicated these issues to be of major importance.

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NOTES

1. This study examines the adoption of MRI equipment, not the provision of MRI services, by hospitals. It considers a variety of acquisition modes including full and partial ownership, leasing, and lease-purchase agreements. Contractual arrangements that did not involve any ownership relationship were considered nonadopters, since distinguishing preferential referral relationships from more binding relationships was impossible. Since our intention was to examine the likelihood of adoption, and not the likelihood of offering MRI services, relationships that did not indicate a concrete commitment to adopt were considered nonadopters. Moreover, the rental of space on hospital grounds by another entity that owned the MRI unit was not considered to be adoption by the hospital, since no explicit decision had been made by the hospital to adopt MRI and there was no resource commitment. Of the 166 hospitals we classified as nonadopters, 84 respondents

said they rejected or had never considered adopting MRI. Of those 84 hospitals, 44 had contractual agreements for the provision of MRI services.

2. No specific hypotheses are made with respect to the moderating effect of uncertainty on CFO involvement. While it is possible that this relationship may be positive, our rationale focuses on the role of the CFO as a proxy for the importance of the economic returns associated with the adoption of MRI.
3. Note that the uncertainty variables are binary measures that were coded as a 1 if these factors had a negative influence on the hospital's MRI adoption decision, 0 otherwise. Thus, support of these hypotheses will appear as a negative coefficient.
4. The G^2 statistic, equal to -2log-likelihood is the goodness-of-fit measure. The likelihood ratio statistic equals the difference between the G^2 values of the nested models and follows a chi-square distribution. The degrees of freedom for the test statistic are equal to the difference in the number of parameters between the two models. If the more restricted model cannot be rejected, it is selected as the model that provides the most parsimonious and best fit to the data (Bishop, Fienberg, and Holland 1975).
5. The pseudo-R^2 is defined as $1 - L^a/L^o$. L^a is the log-likelihood of the alternative model. L^o is the log-likelihood of the null model, which sets all the parameters equal to zero. If the restricted model offers no improvement over the null model, the pseudo-R^2 equals 0. If, however, the model is perfect, then it will be equal to 1.
6. The Akaike Likelihood Ratio Index is defined as $1 - (L^a - K_a)/L^o$. L^a is the log-likelihood of the alternative model, L^o is the log-likelihood of the null model, and K_a is the number of parameters in the alternative model.
7. The technology model, containing all six technology variables plus the control variables, yielded an excellent fit to the data, as indicated by its high chi-square statistic (107.4, 22 d.f., $p = .0001$). The R-value was 14.7 percent, and the pseudo-R^2 and Akaike Likelihood Ratio (ALR) were 4 percent and 5 percent, respectively. All but one of the statistically significant variables had coefficients in the hypothesized directions, and only one of the technology variables, DEVSTRAT, was not statistically significant. The most important factors explaining adoption were the importance of being perceived as a technology leader to the hospital's market development strategy (TECHDEV), and whether the hospital had a high-technology orientation with respect to its product offerings (TECHTYPE). In fact, TECHDEV and TECHTYPE increased the odds of adopting by 68 percent and 104 percent, respectively. Surprisingly, whether the hospital classified being perceived as a technology leader (DEVSTRAT) as its most important market development strategy was not significant. Nor was concern about technological obsolescence (OBSOLTE1) significant, confirming our hypothesis. However, uncertainty about what unit to buy (UNCUNIT1) was negatively associated with the likelihood of adoption, although we had hypothesized no effect. Uncertainty about magnet size and type (UNCMAG1) was borderline significant, but positive, also contrary to our hypothesis. We believe that the results for UNCMAG1 and UNCUNIT1 may be due to the high correlation (.46, $p = .0001$) between the two variables. We did not expect technological leaders to be greatly deterred by these factors.

The clinical model also provided a good fit to the data. The chi-square was 101.43 with 10 degrees of freedom ($p = .0001$), and R-value, pseudo R^2, and

ALR were 12.6 percent, 3 percent, and 2 percent, respectively. In addition, all of the statistically significant variables had coefficients in the directions hypothesized. National and regional referral centers (HOSPKIND), greater involvement in decision making by the medical staff (INVOLVE), and an emphasis on clinical services requiring MRI technology (CLINTYPE), were all positively associated with the likelihood of adoption, as hypothesized, increasing the odds of adoption by 33.2 percent, 30.7 percent, and 75.6 percent. An emphasis on maintaining a traditional service mix, as opposed to diversification (CDELSTRA), was negatively correlated with date of adoption, decreasing the odds of adoption by 28.2 percent. An increase in the number of acute care beds and increased case-mix severity had no significant effects on likelihood of adoption, nor did proved or potential clinical applications.

For the reasons described in the article, two different financial models were run, the first without HMARGIN and the second including it. Since there was no statistical difference between the model chi-square values, as indicated by the differences in their log likelihoods, and the *t*-statistic for HMARGIN was not statistically significant, the latter was not included in subsequent analyses. The chi-square for both models was significant at $p = .0001$, the *R*-value, pseudo R^2, and ALR were 11.4 percent, 3 percent, and 2 percent, respectively. The few variables that were statistically significant had coefficients in the directions hypothesized. Specifically, the anticipated influence of MRI on the hospital's ability to enhance net revenue (NETREV) and the importance of being price competitive to the hospital's development strategy (PRICEDEV) were positively associated with adoption, as predicted, increasing the odds of adoption by approximately 61 percent and 15 percent, respectively. The negative association of concern about PPS on the likelihood of adoption supported our hypothesis as well, decreasing the odds of adoption by 23.3 percent.

It appears that once we control for differences in CON (CONSCORE) and rate regulation stringency (RATEREG), the two control variables that account for the largest proportion of the variance, there is little difference among the three individual theoretical models, based on the chi-square and pseudo-R^2 values. Moreover, the technology model is almost as useful in explaining the variation in likelihood of adoption as the more general full model and provides more explanatory power for the number of variables. In the case of the initial models, if the number of variables added to the model is taken into consideration, as in the ALR, the proportion of variation explained is actually lower for the full model than for the technology model. Thus, if forced to choose among the models on the basis of explanatory power and parsimony, one would select the technology model.

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